STATUS OF RESEARCH IN AMERICAN GEOGRAPHY

One of a series of ten reports prepared by Committees of the Division of Geology and Geography, National Research Council, under contract with the Office of Naval Research

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GEOGRAPHIC CARTOGRAPHY

A. H. Robinson,
Chairman

DIVISION OF GEOLOGY AND GEOGRAPHY
NATIONAL RESEARCH COUNCIL
WASHINGTON, D. C.

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Division of Geology and Geography

National Research Council

This is one of ten reports prepared to evaluate and describe the current status and future potential of research in various fields of American Geography. The coordinators of the study were Preston E. James and Clarence F. Jones.

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GEOGRAPHIC CARTOGRAPHY

During the period of recorded history, from the Babylonian times to the present, cartography and geography have been more or less intimately associated. The relationship is appropriate and necessary, for neither can the geographer deal with differences from place to place on the earth without maps, nor can the cartographer map the face of the earth without an understanding of what is significant. As a matter of fact the earlier geographers might more appropriately be called cartographers; but in the long period since Ptolemy geographic investigation into the meaning of area differences on the earth has been more widely pursued than has the branch of the subject dealing with technical cartography. Today in America, cartography is widely considered merely a means to an end, a tool; nevertheless, geographically-minded cartographers and cartographically-minded geographers are attempting to focus attention upon geographical cartography as a professional speciality

Cartography, as an old and established professional field, is the science of mapping the earth. It encompasses elements of geodesy, geodetic and topographic surveying, photogrammetry, photo interpretation, graphic arts, and others which too often seem to lie outside of the interests and competence of the geographer.[1] But cartography also includes the study of projections, the mapping of area relationships, some elements of the analysis of mapped patterns and associations, the investigation of the results of differences of scale, the methods of cartographic presentation, and the critical appraisal of published maps. These are the aspects of cartography which we include under the term geographic cartography.

The committee which prepared this chapter is as follows: W. E. Davies, P. E. James, C. F. Jones, O. M. Miller, E. Raisz, and A. H. Robinson, Chairman.

Cartography has, in a sense, been rediscovered by American geographers partly as a result of two world wars.[2] More than ever before in America, geographers are conscious of the need for improving their cartographic methods, both in the field and office techniques of research study and in the classroom presentation of geography from the elementary grades to the graduate school. This increase of interest in cartography has come in large measure from the experience of geographers who served in the several agencies of the government during World War II and found their training and background in cartography deficient.[3] Interest in cartography increased sharply during and after World War II and both the broad modern cartography and the narrower geographic cartography fields experienced rapid growth.[4] The resurgence of interest in cartography among geographers and geography departments has been characterized primarily by an increase in the teaching of the subject.[5] Notwithstanding, the interest among geographers and geographic cartographers has been insufficient to develop as yet, except in rare instance, research programs worthy of the name.

THE DEVELOPMENT OF GEOGRAPHIC CARTOGRAPHY

The development of geographic cartography in America has come about because of the work of a small number of geographers during the past fifty years.

During the first half of the present century, geographical interest was applied at two quite different ranges of scales. The macro-geographers worked with small scales, while the micro-geographers were working at scales of less than one inch to one mile. The micro-geographers were interested in cartography primarily as a tool and did not focus their study on cartographic

methods as such. In the smaller scales, geographical cartographers were particularly interested in such matters as the landform map methods of plotting and presenting statistical data, and in the development of new projections suitable for geographical purposes.

The landform map resulted from the work of W. M. Davis and others, who developed the block diagram and the perspective view of terrain to a high art early in this century. Although maps of this kind were prepared earlier, A. K. Lobeck produced the first major contribution.[6] A fresh approach was made by E. Raisz in 1931 when he presented suggestions for symbolizing landforms.[7] Since that time, others, notably Guy-Harold Smith, have also produced physiographic diagrams or landform maps. During the thirty years that have elapsed since Lobeck's first map of the United States the entire earth has been drawn physiographically.[8] During and since World War II some of the few geographer-cartographers possessing this skill made valuable contributions to the National Military Establishment.

The variously titled physiographic diagram type of map is possibly the only type of map which can be claimed as an original contribution of American geographic cartography. It depends, in large part, on a thorough background of landform training which may account for the relatively few cartographers who have worked in this interesting field.

The origins of statistical distribution cartography are not ancient, but it has been slowly developed over a period of at least two centuries, during which time cartography has utilized the iso-line, the point symbol, and the graded shading in more and more useful and complex ways. Geographic concern with cartographic representation of numerical distributions, beyond the well known contour, isotherm, and others, also began early in this

century with the work of O. E. Baker, V. C. Finch, and W. D. Jones. Examples of this kind of cartography prior to the thirties are too numerous to cite, but special mention should be made of W. D. Jones and J. K. Wright whose work with isopleths and ratios led to much wider use in American geography of statistical cartography.[9] This phase of cartography has steadily progressed, and the application of the techniques today are wide indeed. Statistical competence among geographers and cartographers is relatively rare, and although the numerical distribution map is widely used, it is usually based on relatively simple concepts.

The map projection has always had a fascination for the cartographer. As might be expected in geographic cartography, because of its concern with smaller scales, interest in projections has centered on those useful for world or hemispheric presentations. In 1919 J. Paul Goode published a paper concerning the interruption of the Mollweide projection which was destined to attract considerable attention.[10] Later he combined the Sinusoidal and Mollweide projections in an interrupted manner and the resulting graticule, which he called the homolosine, has become a favorite of geographic cartographers in America.[11] Following Goode's example various other interrupted projections were devised such as the Aitoff by V. C. Finch and the Eumorphic by S. W. Boggs.[12] Today the interrupted world projection is often seen in atlases and texts in America, but rarely elsewhere. It is a distinctive American contribution to cartography.

There is considerable skepticism among cartographers concerning the desirability of interruption. Although there is no doubt that interruption reduces the inherent deformation to a considerable extent, the consequent multiple violation of the one-surface earth, and the presentation of it in

pieces, may outweigh the structural deformation gains.

The interest of American geographer-cartographers did not, however, stop with the process of interrupting projections. Concern with the analysis of projections,[13] and the devising of new ones for particular purposes,[14] has increased since the war, brought on no doubt by the growth of interest in seeing the world as a whole. Special mention in connection with new projections should be made of the work of O. M. Miller of the American Geographical Society, whose Miller Cylindrical is widely used at the present time.

There have been many geographers and cartographers who, during the first half of the century, contributed considerably to various kinds of mapping, for example the Land Economic Survey in Michigan and its counterpart in Wisconsin, or the land use surveying in the Tennessee Valley. During the past twenty years various kinds of land inventory activities have been carried on, mostly in the federal government, and geographers have been active but their work was, and is, primarily geographical and not cartographic.

Nothing during the past fifty years has exerted as great an influence on geographic cartography as has the occurrence of two world wars. A considerable amount of the work of geographers in both conflicts has been cartographic, both in federal employment while the wars were going on, and afterward in the period of peace making and reconstruction. Preëminent in this sort of activity during and after World War I was the American Geographical Society. During World War II no agency or individual stood out so clearly, but the representation was large indeed. At least half of the geographic personnel working in the government as professional employees during World War II were engaged in some aspect of cartographic work. It

is to be expected that this would exert a tremendous influence on geographic cartography.

It is not, however, correct to imagine, as some would have us do, that geographic cartography was in the doldrums until the so-called air age forced an awakening. Cartographic activity progressed steadily after World War I and in the thirties the appearance of several volumes, such as Raisz, General Cartography and Deetz Cartography, provides evidence of the growing interest in the subject. The American Geographical Society's Map of Hispanic America at a scale of 1:1,000,000 and the Giant Relief Model of the United States at the Babson Institute were steadily progressing under the direction of geographer-cartographers. But, although those were evidences of a steadily growing interest in cartography, World War II provided an impetus such as had never before happened in American geography.

CARTOGRAPHY AT THE BEGINNING OF WORLD WAR II

World War II caused more cartographic activity to take place in half a decade than in any previous century. As a matter of fact, in some ways the activity of the five years from 1941 to 1946 eclipsed the record of all previous history. For example, the earth was covered by a compiled map at 1:1,000,000; and more maps were made and printed than had been produced in the aggregate up to that time. Extensive military and naval operations all over the earth created a demand for new types of maps, such as the map chart, and a demand for cartographic information such as had never existed previously. These extensive operations, and widespread mapping, brought home to the cartographer the need for adequate world-wide geodetic control. Aerial photography and photogrammetry became a standard mapping procedure, a change

which has already markedly increased the topographic coverage of the world, which is, of course, the geographer's basic tool. Many other accomplishments took place during the war period but it is not necessary to catalog them here.[15] Suffice it to say, that no other event has so profoundly influenced American cartography as a whole, as did World War II. Geographic cartography was markedly affected, and geographic cartographers played an important role during this influential period.

The armed forces of the United States faced a serious problem in cartography upon entry into World War II. At the end of World War I military interest in mapping lagged. The General Staff of the Army maintained only a casual interest in cartography, and utilized only a small staff of draftsmen for routine graphic work; the Engineers were engaged in a continuing domestic program, and had not given much thought to foreign areas. Few plans for mapping in case of hostilities existed. Even with the spread of World War II to global proportions, the tremendous scope of military cartography was not envisioned. The armed forces had taken some steps in 1939 to alleviate the condition, and with the aid of WPA funds and personnel the War Department Map Collection was consolidated, and an attempt made to correct and complete its catalog. A project of compiling a medium-scale map of the United States (Strategic Map 1:500,000) was initiated. Unfortunately, the WPA supplied little help of a professional calibre and the training received, except for those in administrative positions, was of little value. The WPA projects, however, did bring about a realization, to some persons, of the problems involved in the preparation of maps covering large areas, and focussed attention on the requirement of professionally qualified personnel to do the job, as well as for organizing it.

During the partial mobilization of 1940 steps were taken to expand and coordinate existing cartographic facilities to meet the situation that was developing. The greatest problem was the production of maps for the ground forces. In late 1941 the War Department Map Collection was transferred from the General Staff to the Corps of Engineers, and consolidated with the Engineer Reproduction. This consolidation, (after 1942 known as the Army Map Service), assumed the overall responsibility for map production for the ground forces, including the procurement of maps and map intelligence, and the compilation of maps as well as the drafting and printing. The Hydrographic Office of the Navy was more adequately staffed with experienced personnel, and the expansion of its operations was not so much of a problem.[16] The Aeronautical Chart Service did not become a producing organization in its own right until later.

Such, then, was the organization of cartography in the armed forces of the United States at the beginning of World War II. Many basic problems were present, and the most important was the development of cartographic methods that would permit the utilization, with a minimum amount of training, of large numbers of inexperienced persons. The almost complete lack of cartographic training in the United States had produced no reserve of competent cartographers. Of course, the continuing cartographic activities of the civilian portions of the government and of the states were staffed with specialized mappers and production personnel, but cartographers working in soils, geology, engineering, land use, forestry, and so on, did not have the general geographic competence to engage immediately in world wide compilation work.

The major non-military mapping agencies had grown steadily up to the time of the war. The Coast and Geodetic Survey and the Topographic Branch of the Geological Survey were early called upon to contribute to the war effort, by way of technical assistance and other special services.[17] As a result their own work lagged behind, and required renewed effort after the war.

CARTOGRAPHY AND MASS PRODUCTION TECHNIQUES

It was apparent, at the beginning of the War, that success in meeting the cartographic needs could be achieved only by subdividing functions in cartography to the simplest unit and training each person to master only that function to which he was assigned. The traditional and individualistic concept of cartography, wherein design of the map, evaluation of geographic data, and production of a rough draft were vested in a single person disappeared, and in its place came the specialist in specific phases of the cartographic process.

In the early stages the functions were separated into only the major divisions. The gathering and filing of maps and map information, and their evaluation, was one division while the design and drafting of the map was another. At the time of maximum development the major breakdown of functions as followed by most cartographic institutions, large and small, consisted of Planning, Design, Geographic Research, Compilation, and Drafting. Planning responsibilities entailed the initiation of cartographic projects, the scheduling and coordination of the efforts of other units. As such, it was primarily administrative in nature, and served to reduce the administrative functions of the other units leaving them free to perform mainly technical

phases.

The degree to which the main divisions were further subdivided depended on the size and mission of the organization. In the extreme case the subdivisions were large in number and the functions of each were were highly specialized. The Geographic Research Unit is typical of such a subdivision. The general objective of this unit in mass production, applied to cartography, was the procurement, evaluation, and preparation of geographic information for use by the compiling draftsman. The procurement phase was a library problem as far as normal mapping information was concerned. However, in addition to maps a vast amount of intelligence data were being produced by a multitude of government agencies, both civilian and military, that was of value in cartography, and this had to be located, evaluated, and procured. The greatest number of persons, employed in geographic research in map making, were utilized to analyze the mapping and geographic information as collected, and maintain it in progressive, integrated form that permitted ready use. This group of geographers was the key to the mass production technique, as the scope and speed of any project depended on their ability to have data available that were up to date, and in a form usable when called for. To provide such facilities the geographic research was divided into units, each of which was responsible for information pertaining to a specific region or continent. This permitted the geographers to specialize in an area and build up suitable background knowledge. As personnel became available the breakdown was further subdivided until, in many cases, an individual was specializing in a country or a part of a country. It was this specialization that made possible the utilization of a vast backlog of information that had accumulated over many generations, and also permitted current

information to be assimilated.

In the early stages of mass production the geographer not only gathered the data for compiling maps, but also prepared it for use by the map compiler. As there was always an excessive demand for production, it was found that the phase of gathering and maintaining intelligence was not given proper emphasis, or was neglected. To alleviate this the functions were separated and assigned to specialists in each field. The separation assured that progressive intelligence would be maintained regardless of production, and that production demands could be met at the expense of no other phase. This possibly is the ultimate in profitable subdivsion of geographic research for this particular purpose and is the accepted system today. Similar breakdowns can be cited in other major subdivisions in the cartographic process. Mass production techniques were not limited to the large cartographic operation. Even a relatively small organization engaged in geographic cartography, such as the Map Division of the Office of Strategic Services, found it desirable to separate the work of the geographer compiler from that of the draftsman. It should be pointed out that the separation of functions is not a new phenomenon. It was standard practice for years prior to World War II in the American Geographical Society, The Geological Survey, and others. Its significance is that it had not been carried to such an extreme before, nor had it been reflected in the meager training in colleges and universities.

Does mass production in cartography show a profit? That question has plagued all who have worked with it. In monetary terms there is no question it is the best and only method where large quantities of maps are needed in a short period of time. At maximum development the quality of the finished map produced by this type of work seems to compare favorably with

that obtained under the older, more individualistic methods of cartography. Mass production techniques have, however, one serious fault when applied to a professional activity. The professional personnel, especially in subordinate positions, are quite conscious of the piece-meal approach, and frustration complexes are quick in appearing. As a consequence the individual's morale often sags, and the maintenance of his initiative, resourcefulness, as well as his individuality is a large burden for supervisors. This problem will always be an important one when such techniques are employed, for it is difficult to impart to the professional individual a feeling that the final product gives full credit to his efforts.

THE GROWTH OF GEODETIC CONTROL

Little attention by the military in the United States had been given to geodetic control and its effect on world-wide military operations prior to the recent war. Artillery had long made use of geodetic control, of course, but, since previous military operations were confined to relatively small areas, the problem of providing integrated control was comparatively simple. With expansion of military mapping it was obvious that a corresponding expansion in the use of control data must follow. The first obstacle to be overcome was the assemblage of data. World War I, localized as it was in Western Europe, provided little in the way of geodetic control, except in Western Europe. The initial stages in assembly were primarily of a library nature in which all likely publications were examined for the purpose of extracting control data. Initially this was carried on with WPA funds through the Corps of Engineers, U. S. Army (with the cessation of WPA in 1942 the activity was transferred directly to the Corps of Engineers and integrated with the Army Map Service in 1944). After the United States

entered the war agreements on mapping responsibilities with the British included similar agreements on geodetic control with the result that a large amount of material was made available.

Processing of the data followed, and in some cas paral d their collection. The heterogeneous standards on which control s. are based made it necessary to reduce the data to uniform standards before making them available in integrated form. The collated information was furnished to users in lists keyed to specific maps.

A special problem involving the use of control in aerial mapping was of increasing importance in enemy held areas. Since the country was inaccessible to field parties that could identify the control on photographs it was necessary to locate the points from the available descriptions. This need emphasized the importance of accurate descriptions for control points and much of the effort in getting data was spent on this phase.

The impetus given to international control adjustments bore fruit after the war when central and western European nations entered into cooperation with the International Geodetic Association for recalculation and adjustment of control in their areas.[18]

Other countries, recognizing the fundamental importance of adequate integrated geodetic control became similarly internationally minded. A large program of cooperative mapping was initiated in 1946 among the nations of the Americas. The need for geodetic control and for such international cooperation is well illustrated by the following extract from an account of the work of the Inter-American Geodetic Survey:

> "In Costa Rica, a pilot obligingly flew (the author) over a peak charted at 4,500 feet which we barely cleared at 9,500.

"Our geodetic reconnaissance information alone has caused several aeronautical charts to be declared "hazardous". Pico Trujillo in the Dominican Republic is being moved over about 35 miles and raised 2,000 feet in elevation. It appears that part of the huge Xingu River in Brazil may be 30 to 40 miles from its true position on our aeronautical charts and maps.

"Plotting the completed geodetic nets on existing maps reveals some amazing errors. The coastline shown on the existing Costa Rican map had to be moved several miles so the geodetic stations would not be plotted into the Pacific Ocean. In Cuba, some stations have proven to be as far as 6 kilometers from their large-scale map positions and, in one case, on the wrong side of a town, a road, and a railroad.

"A recent astronomical observation indicates that the Isle of Pines, just south of Cuba, may be nearly 18 miles out of position. This is a serious discrepancy, as the island is used as a check point by aircraft approaching the Habana airport.

"In Eastern Peru, a large river is out of position by 10 miles."[19]

Geographers are concerned with differences from place to place and geographer-cartographers are concerned with their mapping. The geodetic work given such an impetus by the war will help to make known where places are.

THE DEVELOPMENT OF MAPPING FROM THE AIR

At the beginning of World War II aerial photography was by no means as fully employed as it should have been for cartographic purposes. In commercial and industrial work it had been developed extensively as an efficient instrument for mapping, but mapping agencies of the Federal Government had been relatively slow in accepting it as a method of producing topographic maps. Only the Department of Agriculture, through the AAA, had accomplished photography approaching in scope that which was to be demanded for war use and in this case only a small percentage had been translated into maps.

Just prior to World War II the Army had accepted multiplex methods as standard for its use in producing topographic maps from aerial photos.[20] This

system was satisfactory for topographic mapping, but lacked the necessary flexibility to permit its use in reconnaissance mapping of vast areas.

The Pacific and European theaters of war presented two distinct problems in aerial photography and mapping. The European theater had fair to good maps over much of the area, and medium and small scale maps could be compiled from existing maps, while large scale mapping could be revised or extended by use of multiplex and large scale vertical photographs. In the Pacific theater conditions were the reverse; large scale maps were lacking. At the start of the Pacific war American troops were forced to use hopelessly inadequate maps. In the Philippines this amounted to an out-of-date, inaccurate series covering Luzon. In the East Indies it was a case of accepting Dutch maps in Java and on some of the larger islands. Elsewhere there were no maps, good or bad. With the stabilization of the Japanese operations at Guadacanal, the days when only resourcefulness counted were at an end. The road back was to be paved with maps, practically the whole way. In the case of large scale maps, aerial photographs and multiplex methods gave the answer, but for small scale maps and charts that must precede the large scale work the answer was not so easy.

Just prior to the war the Army Air Force had begun experimentation with trimetrogon aerial photography as a means of producing medium and small scale aeronautical charts. The trimetrogon system[21] consisting of three cameras arranged to take a vertical and two related obliques photographs such that the three photographs form a continuous photostrip, horizon to horizon. While this was not the first use of combined vertical and oblique photos to produce a map, it was the first devised specifically for the production of small scale maps or charts.

The capacity to cover vast areas with aerial photographs was increased tremendously by trimetrogon photographs. Practically all of the theaters of operation, plus the supply routes leading to them were covered by "trimet". Obscure sections of equatorial and northern Africa, the eastern Himalayas, Alaska, parts of Latin America, and South Pacific islands were first seen in cartographic detail as a result of such photographs.

The increase capacity to cover vast areas with aerial photographs has not been matched in methods available for the cartographic utilization of trimetrogon pictures. Planimetric features, through an intricate system of lattice "lay-downs", can be plotted with accuracies commensurate with detail necessary for medium and small scale maps. Relief, however, is more difficult to achieve and in general is portrayed far less accurately than the corresponding planimetric features. Improvement may be expected with contimuing research, but advances in high altitude flight, and its utilization in photographing, makes it possible to obtain vertical photographs usable in precise multiplex mapping at costs comparable to trimetrogon photography. Such developments leave the ultimate refinement of trimetrogon photography in a questionable state.

There is no question that the displacement by the air photograph of the plane table as the primary tool of extensive mapping operations is a cartographic revolution in itself, but the direct impact of airplane photography is on the mapping aspect of cartography rather than on geographic cartography. Negertheless, it also affects geographic cartography, the art of expression of the earth's patterns collected from individual surveys the world over. Not only is the survey of the most inaccessible parts of the world possible, but the cameraman works infinitely faster and cheaper

than the man with the plane table and rod on the ground. The United States, from the Atlantic to the Pacific, was crossed and photographed in a single flight, bringing in a wealth of information which no surveying party would be able to collect in years of work.

The increase in the amount of coverage by aerosurveying is prodigious, but for the cartographer the type of information is just as significant. Airplane photographs provide a richness of detail that makes its utilization for maps employing the present conventional symbols a problem. Perhaps a new type of map will develop.[22]

The use of aerial photography made it a practical procedure to enlarge the scale of topographic maps in the United States and to depict contour lines more exactly and expressively than previously. The new U.S.G.S. sheets are on a scale of 1:31,680 in New England, and the others are mostly 1:24,000. Geographers welcome these detailed maps, but it will take years until they will be generalized into medium- and small-scale maps.

THE DEVELOPMENT OF NEW MAP TYPES

By all odds the great majority of maps produced during the immediate past have been of conventional types, but the immediate past has seen the rise to prominence of several kinds of maps, and other cartographic productions, which have never before risen much beyond the experimental.

Chief among these is the aeronautical chart. Prior to the war aeronautical charts were much like the conventional topographic map, but on a smaller scale.[23] Some experimentation had been undertaken during the thirties and earlier, but did not immediately result in any new maps.[24] With the coming of the war the needs mushroomed, and the increase of speeds and varying flying conditions required new types of maps.[25] Target charts,

approach charts, special navigation charts, (electronic and otherwise), many others are required for the specialized needs of the air navigator and pilot. Civil, military, and private aviation require different kinds of charts on different scales. In order to meet these requirements, in a reasonably integrated fashion, there has been established an international organization (International Civil Aviation Organization) which has arranged standardization of these types of charts to a considerable extent.

The term special purpose map has been applied broadly to a variety of chorographic maps. For descriptive purposes these maps can be divided into two groups: the interpretative and non-interpretative types.

The interpretative maps are designed to present an interpretation of facts rather than mere facts themselves. Maps portraying terrain appreciation ("Going"), bomb vulnerability, or industrial potential are typically interpretative. The Military Geology Unit of the U. S. Geological Survey produced the majority of interpretative maps dealing with physical conditions. In most cases these maps were part of a detailed intelligence study, although separate maps or series of maps on specific subjects or areas were common. Scales varied but tended to be in the range of 1:250,000 to 1:1,000,000 with larger scales where maps were designed for a specific operation.

The physical interpretative map did not originate in World War II. The Germans had made extensive use of them in World War I, and their development can be traced well back into the 19th century. However, their broad use in America was initiated during World War II.

Interpretative maps in other fields were prepared by several non-military agencies. The Office of Strategic Services, Board of Economic

Warfare, and the Division of Geography of the Department of State were among more important producers. Within the military establishment various intelligence organizations, as well as units of the Quartermasters Corps, issued interpretative maps covering subjects other than terrain features.

Non-interpretative maps produced during the war covered subjects that were closely allied to those covered in the interpretative types. Water supply, landing beaches, and construction materials in the field of terrain maps, and political, economic and population in non-terrain maps were prepared for all zones of potential military operations. The majority of these maps were integral parts of special reports and were designed for use with accompanying text. However, a number were issued separat ly, and in some cases the same map appeared both as a part of a report and as a separate.

The non-interpretative map was generally on a small scale and covered large political or regional units. It was primarily for planning purposes, and as such was used by the highest echelons. It was issued as a general coverage map and multi-sheet sets were seldom published.

Terrain models have been used to portray earth features almost as long as maps. However, their direct connection with cartography had been given but slight recognition in America prior to World War II. During the war both the technique of production and the utilization of terrain models advanced greatly. Prior to the war, model making was a craftman's job, devoid of any mass production possibilities. The cost in time and money prohibited great numbers of models. During the war the demand for models for use in service schools, for planning purposes, for briefing troops in special operations, and for terrain recognition of bombing targets increased to such an extent that model making, as with other phases of cartography, was converted to

mass production techniques.

The Map Division of the Office of Strategic Services established a model section in 1943 that produced the bulk of models used during the war. At the end of hostilities this unit was incorporated in the Army Map Service. In addition to the OSS unit, several model making detachments were active in the various theaters of operation. At first plaster of paris or papier mache was used and molds were cut and cast by hand. As the demand increased cutting machines, special projectors, and special casting methods and materials were introduced. Among the latter was the use of sponge rubber that permitted a large model to be rolled for ease of shipment or storage and increased its durability.

Production of plastic models utilizing standard maps printed on plastic, and molded by heat around a master mold, was developed by private concerns during the war. Although the method was used sparingly in war time it is now meeting an increased demand for models of use in teaching.

The concern with terrain representation was not limited to the three dimensional map. The search for graphic means of representing the land surfaces on medium and large scale maps is an ancient struggle. With the increase of air navigation, with the increase in popular interest, and in the number of map users, the development of methods of providing a graphic impression of relief have grown apace.[26] Today, for the first time the standard topographic maps of the United States are appearing with shaded relief expertly applied.

The development of aerial cameras, rectifiers, and halftone screens capable of retaining detail on printed photo mosaics led to the use of photo maps. They were used extensively in World War II as both training aids

and for operations where satisfactory topographic maps were not available. The largest project was the coverage of northern France by photomaps at a scale of 1:125,000 for use in the Normandy invasion and subsequent operations. The major problem, given good photography, of mosaiced photomaps is, of course, control, and the necessary rectification of the photos to permit the preparation of controlled mosaics sufficiently accurate that they may be gridded. In areas of relatively high relief, models have been used as a terrain background for map data. Photomaps and model photomaps are destined to remain in general use.

THE DEVELOPMENT OF MAP LIBRARIES AND MAP ANALYSIS

When cartographers and geographers were called upon during World War II to compile from foreign maps, and thus evaluate them in all manner of ways, it was brought home to them that they did not have much familiarity with coverage, availability, quality, symbolism, and all the other aspects needed to analyze and utilize varied maps from diverse sources. This led to the establishment of units specializing in, what was called during the war, Map Intelligence, and this evaluation of maps and their inherent qualities has continued and expanded up to the present.[27] Paralleling the growth of this cartographic counterpart of literary criticism has been the expansion of map libraries and their holdings. The governmental holdings in the Army Map Service, Library of Congress, and others have grown phenomenally primarily due to the activities of geographers. University departments of geography have benefited tremendously from the Depository Program of the Army Map Service, so that adequate foreign map types and coverage is available for instruction. The increased use of maps has made necessary the establishment of facilities for channeling requests and providing general analyses of coverage quality

such as the Map Information Section of the Geological Survey.[28] Publications related to this aspect of cartography since the war are numerous indeed. The increase in the number of articles appearing in American journals concerning map resources of various parts of the world is a welcome addition to cartographic literature.[29]

The cataloging problem always a difficult one, also brought forth a flood of papers.

CURRENT STATUS OF CARTOGRAPHY

Cartography of the forties affected many geographers and awakened their realization of the broad relationship between geography and cartography. War-time experience showed that geographers, in the main, are equipped to handle many phases of cartography, especially those involving source material, map compilation and editing, small-scale projections, landform presentation, and statistical distribution, and interpretative cartography. The present emphasis within geography on these phases of cartography is in marked contrast to conditions before the war, when the cartography of geographers was primarily a research tool or a draftman's job. The field of geography has received considerable benefit from its wartime contact with cartography. A better understanding of the use of maps and their specialized adaptation for portraying geographic data has been achieved by geographers in all phases of the science.

At present we are at the threshold of a new age in the history of cartography, comparable to the beginning of the 16th century. At that time the great discoveries, the revival of learning, and the invention of engraving and printing combined to produce an unparalleled outburst of map activity. Factors of similar importance are working at the present time, among which

the more important are the airplane, photography, and electronics. New techniques in the preparation and reproduction of maps, models, and globes make it possible to create new types. But in addition to the technical advance, the profession has progressed to a greater and wider understanding of maps. An awakened interest in the earth as a whole and the interrelation of its various lands, together with the political necessity to widen our horizon until it reaches across the globe, gives both cartography and geography an incentive to which they must respond.

Airplanes make possible travel to hitherto inaccessible regions with consequent improvements in map coverage and quality. The mysteries of the Antarctic, the Amazon forest, the Sahara and many other places are being revealed by air exploration. It is particularly in the difficult regions where the airplane shows its greatest value. Even if systematic photogrammetric surveys of these huge areas cannot be accomplished immediately, test flights along selected lines will reveal much of cartographic value.

The map draftsman of the past was a highly specialized craftsman, drawing hachure lines, or lettering with infinite patience and perfection. Once a map was drawn it lasted; changing it was costly. At present, nearly anyone, often with short training, may stick-up the most perfect lettering, and lay cellophane tints fast and efficiently. Machines can lay out projections; shape-proof plastics help to eliminate lack of registration; glue-pigment processes make color proofs possible; and maps are produced cheaper and faster than ever before. Papers are better than in the past, and offset machines running with incredible speed turn out copies by the millions, some of them printing two to four colors in the same operation.

Governmental agencies produce at present many times more maps than

private industry. There is scarcely a place on earth which produces more maps than Washington, D. C. Among other aspects of government mapping, the enormous increase in coverage should be noted. The whole earth on 1:1,000,000 (not all government, of course) is an almost-accomplished fact, and most parts have 1:500,000 scale coverage, although the information on which they are based is sparse and of poor quality in many instances. For large-scale maps the Transverse Mercator seems to be becoming a favorite, particularly after the adoption of the Universal Transverse Mercator grid. It is not impossible that the use of this projection will spread to air navigation charts. Map symbolism is undergoing a change, and will change a great deal more before the true portrayal of the earth is achieved. Plastic shading is now an accepted feature as an addition to contour lines. The number of colors is growing; the 1:250,000's of the United States have seven colors.

The most significant fact about government mapping, however, is its variety. With Washington employing more than half of the country's cartographers, and producing an even-larger proportion of map copies, cartography faces a problem of development. Not so long ago the government was concerned only with topographic maps and marine charts; at present it engages in every kind of activity requiring, in quantity, the entire gamut of cartographic types. Many of the best cartographers are employed in Washington, but there they do specialized work and of a set standard; rarely can they develop their full talents, and rarely can they engage in any pure research in the field of cartography. Universities cannot compete with the government in terms of salaries; consequently there is a steady movement of cartographers to Washington, while the number engaged in scholarly research remains small. A field cannot progress without development of its

theoretical base.

A large proportion of the materials and sources necessary for cartographic research and teaching, along many lines, is held in military agencies, and they are unavailable to the profession as a whole. No proposal is made to alleviate this stagnating situation, but the vicious educational circle in which the teaching and research cartographer finds himself is obvious.

The tremendous changes of the past several decades places a heavy responsibility on the geographer-cartographer who is part of a geography department. He must try to keep abreast of the multitude of technical developments taking place in the field; he must try to teach and train these modern techniques; and most important, he must carry on research in order that the field may advance. Of necessity this research must be aimed at the benefit of geographic cartography. If he fails in this last he will find that his portion of the vast field of cartography will not progress but will ultimately stagnate and be staffed by clever draftsmen. The number of geographer-cartographers of the past in American universities, colleges and societies who helped to promote the field by their research are few in number. There must be more, for as the appreciation and use of cartographic techniques has increased so has the need for research.

THE PROSPECT IN GEOGRAPHIC CARTOGRAPHY

There seems to be no question that most of the research carried on in the field of cartography will be in the government or under government contract. It is not the purpose of this chapter to consider in detail the merits of such a condition in a profession; but rather to forecast possible avenues of research which seem desirable for the profession as a whole and which may be reasonably carried on without vast technical facilities.

Governmental cartographic research is dictated by current needs, and, in general, will rise and fall as the technical and practical requirements change. ... o large a proportion of the research being pursued is of that nature. ...lati... ly little research is being done in Universities and by non-governmental agencies. This is an unhealthy situation.

The question may be asked, when advantages in terms of technical and financial support, and in terms of numbers of competent workers, all lie with the government, what is left for the scholar and independent research cartographer? The answer is not in any way discouraging. The following categories and suggestions are neither complete, nor are they necessarily organized in such a way as to outline the field of cartographic research. They are merely the more obvious avenues.

Projections

At a time when this country has awakened to the fact that it is but part of a whole earth, nothing can be of more lasting significance than the study and teaching of projections. The erroneous space concepts of the majority of Americans is living proof that our present level of projection-understanding is wanting. Particularly important is the projection for large areas or the whole earth. Our standards of choice, by and large, are biased in conventional terms. We are unwilling to experiment with the vast number of possibilities. For example, most projections can be made oblique in infinite variety with very little effort, yet the departure from the ordinary is looked upon with suspicion. Perhaps if there were more work done by cartographers on the variation of projections, and circulated in the professional journals, there would be less tendency in the geographic profession to judge projections on the basis of familiarity. Perhaps the

greatest advances can be made in the employment of equal-area projections.

Much of the negative attitude toward projections among geographers (and cartographers) may be blamed on inadequate teaching. Except in rare instances, the student is left with little appreciation of this fascinating subject, and with no desire to construct his own or even to be selective. New methods of teaching and analysis of projections are necessary.[30]

Representation of Terrain

The shift in geography from the genetic approach in landforms to the geomorphological has not been accompanied by a similar shift in cartography. Studies of presenting form relationships are conspicuous by their relative rarity.[31] With the increase in the use of terrain drawing and shading, studies in the relation of scale and detail of regional presentation are necessary. There has been little study, in this country, of the actual visual efficiency of landform presentation methods, not even along the line of analysis of the favorite device, the contour.[32] Although, as was pointed out earlier, American cartography can take great pride for the development of physiographic and landform drawing, through the work of Raisz, Lobeck and others, little has been published concerning general methods and particularly the teaching of this art.

Statistical Presentation

Perhaps in no other aspect of cartography is the opportunity for important research greater than in the field of presenting numerical data on maps. With the increase of regional analysis for planning purposes, mapped ratios and correlations are assuming a greater importance. Studies of presentation efficiency are sorely needed. Even the time-honored dot

map is capable of considerable refinement as has been shown by Mackay.[33] Probably more important in the long run will be studies on the nature and employment of isometric lines and isopleths.[34] The selection of intervals and the placing of the isopleths is a particularly important problem requiring further research.[35] No less important is the visual problem of creating in the mind of the reader the correct impression the cartographer wishes to convey. This problem of tonal relationships is particularly complex and relatively little has been accomplished so far.[36] What has been done has been aimed at the range of black and white values, but equally important is a systematic approach to the value problem in the use of color. A considerable amount of experimental and analytical research is being done in other fields and is available in the optical and psychological journals, but it does not seem to percolate through to the cartographic researcher. A conspicuous exception is the research being carried on by some governmental agencies in the field of map design.

An interesting avenue of research which may reveal results of considerable value is the analysis of the characteristic shapes and occurrence of shapes of various types of isograms. Isogram is an inclusive category referring to those lines which pass through, or join, points of equal value. Wright has made the sensible suggestion that those lines joining points at which an actual value does or can occur be called "isometric lines", while those lines used for presenting information which cannot exist at a point, e.g. density of population per square mile, should be called "isopleths".

All geographers and cartographers are familiar with the large amount of information that can be gained from the shapes and patterns of contour lines. So far as is known the study of isogram patterns has been limited

to the contour, but there is no reason for believing that equally informative and interpretive results could not be revealed by careful research with other families of isograms. Isometric lines, because of their relative precision, will no doubt be the first class to reveal inherent relationships. Isopleths, if their precision can be controlled in any way may also be subject to analysis in this fashion. Many interpretations and correlations from known to unknown may be possible through such research.[37]

Cartographic Design

An interesting field of research is that connected with the techniques and media of presentation. If a map cannot be read, for any reason, it is thereby a failure. The poor quality of cartographic design in many maps is well known. Only by investigating the visual techniques can the cartographer become competent in design. A considerable amount of research in the visual aspects of presentation has been accomplished in other fields, but for some reason the cartographer has not matured far along this line.[38]

Lettering is one of the more important problems that is included in this category. Practically no research has been done on the problem of styling and selecting lettering for cartographic use. Freehand lettering which can be fitted and styled as necessary is being replaced by various forms of stick-up. So far as is known only the stick-up of the National Geographic Society has been designed specifically for cartographic use.[39] Type designed for reduction and for curved positioning is a definite requirement. Further work on readability and relative visibility of lettering on different map backgrounds is necessary.[40] The entire gamut of presentation techniques requires research. Relative line weights, balance, layout, movement, and the like, as applied to cartographic presentation, are

capable of such infinite variation that the cartographer needs experimental evidence to aid him in his choice of media and technique.

With an ever increasing amount of cartographic production being centered in the government, it is likely that the paralysis of standardization may spread even to the small-scale map. If research is undertaken to expand our understanding, and, at the same time, to point up our genuine ignorance of fundamental aspects of cartography, then cartography can continue to advance in more than the mechanical sense. Standardization within map series and in topographic scales is an obvious necessity, but it should not invade the entire field of cartographic technique. Even the standard conventions need investigation. For example, testing has shown that when people are asked to grade and rank graduated circles drawn in strict area relationship with the values they represent, the readers consistently receive incorrect impressions. Clearly, grading diameters according to the square roots of the data is an incorrect technique. Some other curve is necessary.[41] The facility with which cartographic techniques can be and are misused is ample evidence of the need for further research.[42]

During the past several decades tremendous strides have been made in the understanding of color and its visual relationships.[43] Little of this has spread to cartography and, so far as is known, no actual research on color in cartography has been undertaken since the turn of the century anywhere, and none in America. Such subjects as visual acuity, stereoscopic effects of colors, simultaneous contrasts, and a host of others need investigation as they apply to cartography.

The tremendous strides made in the past few decades in the field of map production, particularly reproduction, makes it necessary for the

cartographer continually to investigate ways and means of preparing his map and of reducing the costs. For example, the size of classes in schools seems to be becoming steadily larger, and the usual wall map is too small to be seen. Yet larger wall maps are, when prepared according to current techniques, too costly. The development of the newer techniques of color reproduction makes a wide range of effects possible. The application of these to cartography requires investigation.

Mapping analysis

It is rather surprising that a tool as indispensible to the geographer as the topographic map has not received more attention from geographer-cartographers. To be sure, the shortcomings of the United States topographic coverage and quality has often been considered in a general way, and frequently overemphasized, but very little real research on the quality, and coverage of topographic mapping took place until World War II. As was pointed out above, the sudden requirements of using foreign topographic maps of large areas made it startlingly clear that American understanding of this subject was inadequate. Since that time there has been an increasing amount of this kind of research.

The most important facet of this complex research problem is probably the inventory aspect, that of finding out exactly what mapping there is, its availability, and particularly its quality. The latter requires searching out the geodetic control bases of the maps, the methods of survey, the dates of production, and a host of other less important aspects of mapping. Only when that is done on a regional basis will the geographer and cartographer have a proper understanding of the major source of his information.

Allied to such research are other, more specialized aspects. For example one of the great needs today is for an up-to-date coverage of minor political boundaries for census analysis around the world. The problems are interrelated and continuing ones, for the boundaries are constantly changing. The significance of this kind of research can be illustrated by pointing out that areas of minor civil divisions cannot be determined except from a map and if they have not been accurately mapped any such areal data can be at best only approximate.[44] Ratios and correlations depending upon area determination of minor civil divisions are basic geographic tools. The area of the minor civil division is but one of many similar items of great concern to the geographer and cartographer. Slope and other landform analysis can not be properly derived from contour maps without considerable understanding of their quality.

A very interesting and useful research field in cartography, historical cartography, has not been developed in recent times in America to the extent it has in Europe. It is surprising for it is a research subject which has a large literature (largely foreign) and which has a great deal to offer to the historical geographer. The spread of geographical ideas, the movements of peoples and so on are reflected in the maps of the day. With the reappearance in 1948 of Imago Mundi,[45] and Lloyd Brown's volume[46] it is to be expected that historical cartography will gain in interest in America.

CONCLUSION

All in all the geographic cartographer need not want for interesting avenues of research. Everything considered, he is living in a time of rapid change in techniques, accompanied by an almost revolutionary expansion in material and interest. He requires only the desire and freedom

to experiment with the immense possibilities brought about by these changes. Today he can accomplish almost any result he may desire. The problem is not so much one of "how to do", but one of "what to do".

The greatest danger in geographic cartography is the possibility that the developmental and production aspects, as exemplified by the federal government, will outstrip and take precedence over the theoretical base upon which such activities should depend. The widening of the theoretical base is the fundamental function of the academic cartographer. It can only be hoped that the increasing calls upon the geographic cartographer for teaching and production will not stifle the essential research.

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4. An example is the phenomenal growth of the American Congress on Surveying and Mapping, a professional organization representative of "modern cartography," founded in 1941 and now affiliated with the National Research Council as a constituent society of the Division of Geology and Geography. The Technical Division on Cartography, one of several divisions of the Congress, is primarily concerned with geographic cartography and has several geographers among its officers. Also it should be mentioned that the Association of American Geographers established a Committee on Cartography which has functioned with great success. Two entire numbers of The Professional Geographer have been devoted to cartography.

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